CARA Devolution

ESMO Pilot Program

Dimitrios Mantziaras, Terra Mission Director

December 4-6, 2018

ESMO Pilot Program Overview

- **ESMO was asked to be the first to exercise the CARA Devolution process**
  - ESMO's extensive history working CA and working with CARA
  - ESMO's maturity with DAM process & SpaceNav tools
- **Goal is to collaborate with CARA in creating a plan on how to devolve. This plan will be used as a template for any future mission going through the devolution process**
- **Established a Devolution Working Group (started on June 27th, 2018)**
  - Members of Working Group include CARA, ESMO Management, Mission Directors, FOT & Flight Dynamics
  - Started as a monthly/bi-weekly meeting and moved to every week for the last several months prior to Parallel Ops start
  - Collaborative effort to layout a plan for devolution and complete all prerequisite activities

Devolution Working Group

- **One of our first work items was to define which documents we thought should be created to govern this project**
  1. Memorandum of Understanding between CARA and ESMO for Devolution Pilot Program (MOU)
  2. ESMO Mission Operations Conjunction Assessment Concept of Operations (MOCA ConOps)
  3. Pilot Parallel Operations Plan
  4. Tool Certification Plan

- **Additionally we needed to setup dual independent paths for data flow to and from CSpOC (formerly JSpOC)**
  - Existing flow through CARA
  - New flow using SpaceTrack to send and receive data

Devolution Working Group (cont)

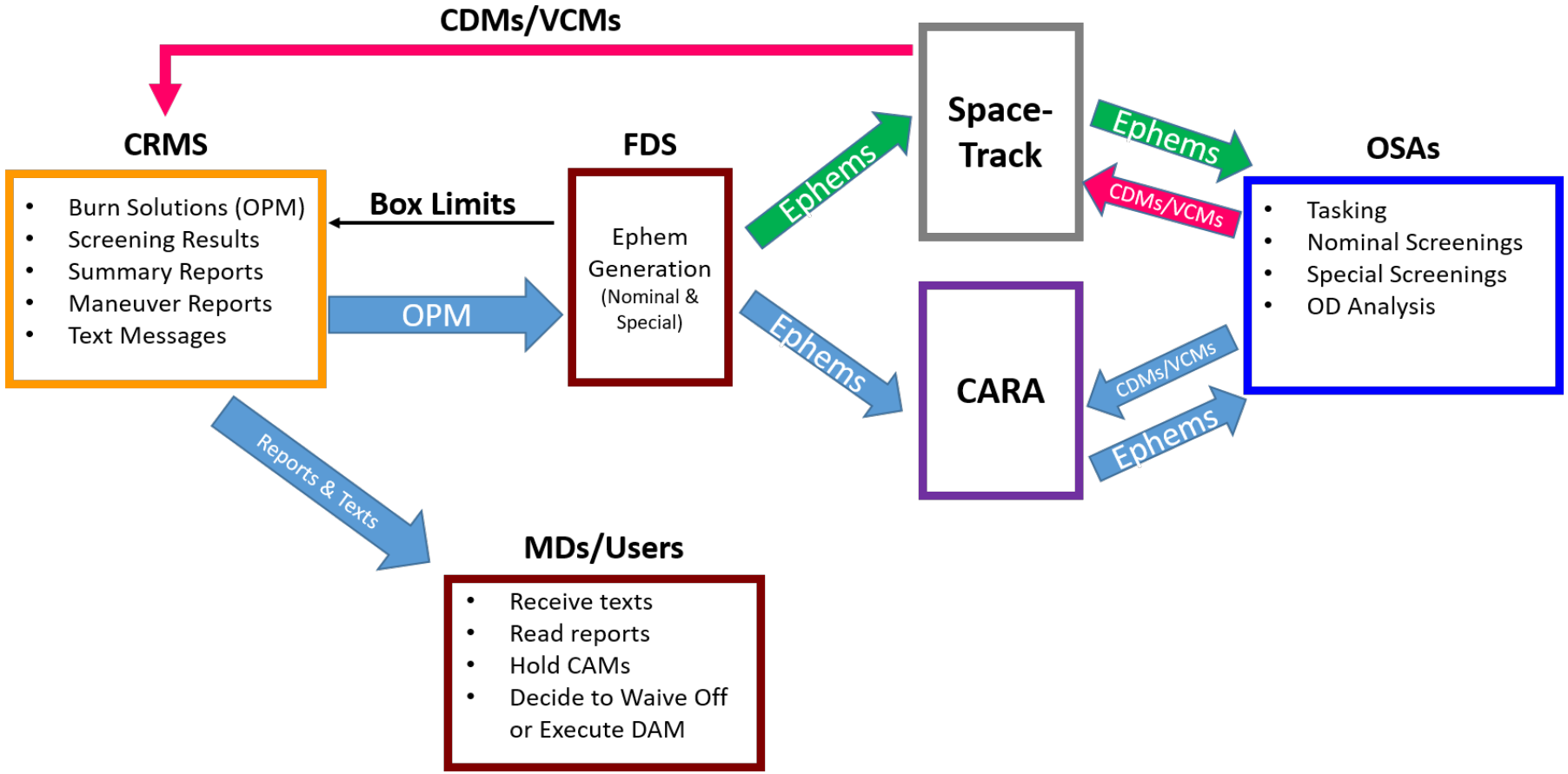
- **Needed to make a software update on Flight Dynamics automation to build ephem names that work for SpaceTrack and CARA**
  - Software change implemented on 11/15
- **Perform Tool Certification**
  - Run SpaceNav tools through predefined cases generated by CARA to ensure system can perform all required functions to support operations
- **Held Internal Test Readiness Review (TRR)**
  - Review what we had been agreed upon
  - Gate for starting Parallel Ops
  - Opportunity to double-check that we hadn't overlooked anything in our preparations

Actions needed to begin Parallel Ops

Required Actions	Status	Due Date	Comments
1) MOU Document	CLOSED	10/19/18	**CLOSED**: Reviewed all comments on 10/17, Dimitrios sent out final "clean" version on 10/23
2) Setup Ephem Delivery	In Work	10/01/18	• OSA Developer working on updates for parallel paths and delivery through SpaceTrack. CARA reported Dave is on schedule for 10/1 – **Need Status** • Test ephems being delivered by EOS FDS to SpaceTrack 3x/week. Need splinter meeting to discuss test configurations and when to turn on
	In Work	11/15/18	• FDS will maintain 2 filenames. Updates to be made on 11/15
3) Parallel Ops Test Plan	In Work	10/26/18	Action to CARA. Met on 9/05 to review success criteria; ESMO incorporated comments and sent back out to group for review on 09/13; Met on 9/19 for final review, ESMO incorporated updates and sent out on **9/25**
4) Tool Certification Plan	In Work	10/26/18	Action to CARA. ESMO met internally to review document; feedback typed up and being reviewed; sent out updated version on 9/13; reviewed on 9/26 – updates incorporated and sent on **9/26**, CARA to fold into document
5) Ops Concept Document(s)	In Work	10/31/18	Action to CARA & ESMO • Reviewed lastest verison on 10/17; CARA to provide sample write-ups to help explain level of detail they are looking for, ESMO to fold in comments and add new Special Cases section • CARA Ops Con draft in work – targeting 10/17 for completion
6) Tool Certification	Not Started	11/16/18	Action to ESMO. CARA has provided all but one of the test cases. ESMO met to discuss testing methodology (10/11). SpaceNav evaluating test cases and will determine schedule.
7) Internal TRR	Not Started	11/20/18	Tentatively set review date – NASA management does not require this review. Will hold internal review just to summarize what we have agreed upon

Ephemeris Delivery Setup

- Dave Ward has set up script to allow for parallel paths and delivery through Space-Track
- The FDS team has configured and setup ephemeris file transfer using the Space-Track REST API
- The ephemeris flow will be as depicted below, to ensure that both ESMO and CARA receive all data for the ESMO missions:



Tool Certification Plan

The following tool features have been tested and approved for the TRR:

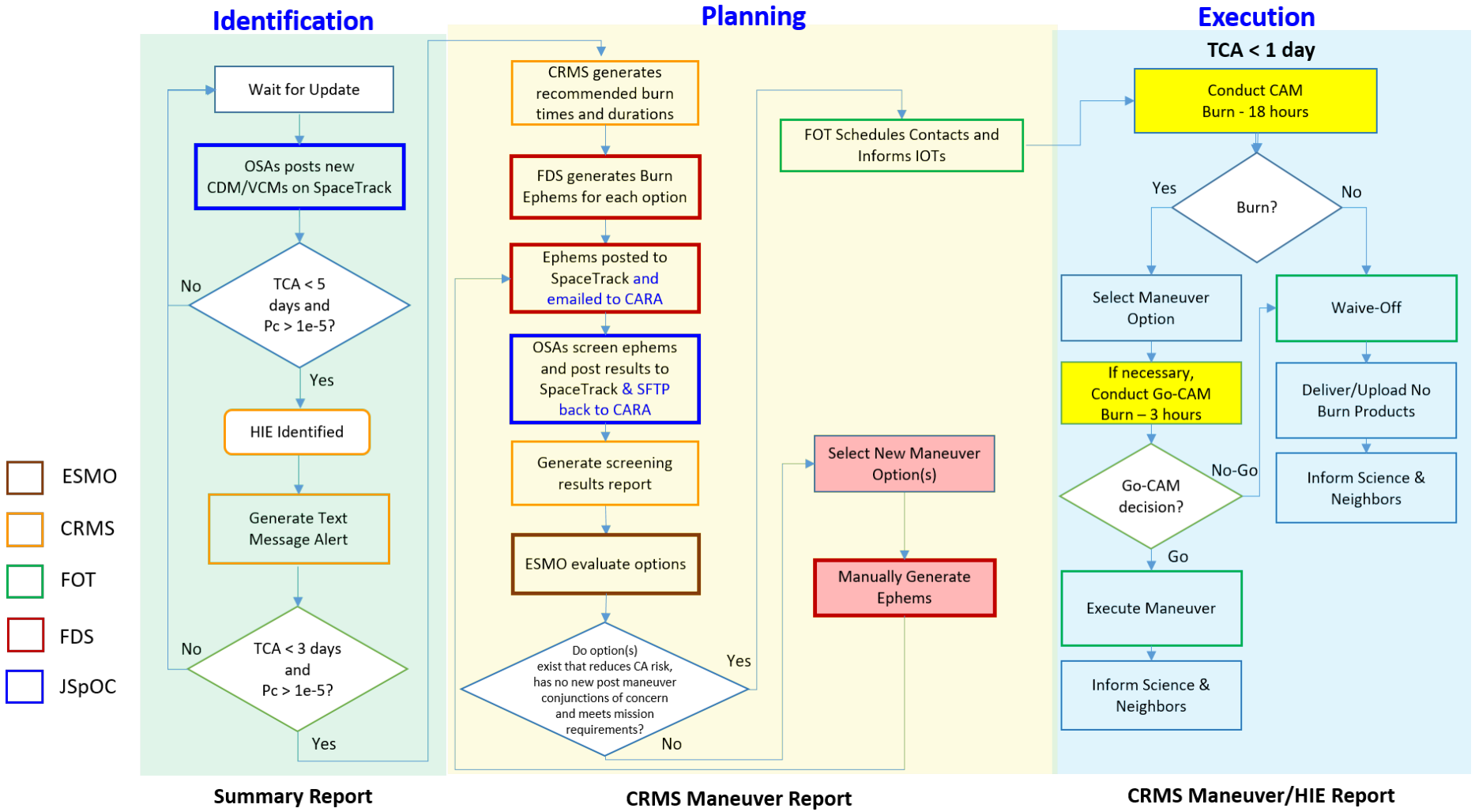
Tool Feature	Topical Area	Test Completion Date
T-1.1	Miss-Distance Reporting	
T-1.2	2-D Pc Calculation from ASW data	
T-1.3	Flag when 2-D Pc Calculation from ASW data is Non-Positive Definite	
T-1.5	Indication of 2-D assumption inadequacy	
T-1.6	Owner/Operator Ephemeris/Pc Calculation	
T-1.7	Identify and flag Missing Covariance for Pc Calculation	
T-1.8	Covariance Synthesis Capability	
T-3.1	Historical Pc Trending (Event Histories)	
T-4.1	MTS: Single Conjunction	
T-4.2	MTS: Multiple Conjunctions	
T-4.3	MTS: Execution Error	

The following tool features will be tested and approved during the Devolution Pilot Phase:

Tool Feature	Topical Area
T-1.9	Monte Carlo from TCA: equinoctial frame
T-1.10	Position Monte Carlo from Epoch
T-2.1	Covariance mis-sizing sensitivity
T-3.3	Tracking Prediction
T-5.1	Loading Performance Test

Parallel Operations Period

- The Parallel Operations period began on 11/26
- The ESMO CA Operations decision making process during this phase is depicted below:



Parallel Operations Period (cont'd)

- **The communication between ESMO and CARA during the Parallel Operations period will be as the following:**
  - A daily email will be sent from ESMO to CARA describing each HIE that is being actively planned and worked, and the action that ESMO is planning on taking
  - A weekly email will be sent from ESMO to CARA listing the progress toward achieving the parallel operations success criteria
  - The CARA team will remain on distribution for ESMO HIE communications and CAM invitations associated with DAMs/RMMs during the parallel operations period
  - At a minimum, 2 members of the CARA team will be in attendance at all ESMO planning and review discussions
  - A monthly email will be sent from ESMO to CARA with the HIE metrics
- **During parallel operations, ESMO will contact NASA Headquarters to report any red event which is less than 2 days from TCA, including the proposed remediation, on an as-needed daily basis**

Parallel Operations Success Criteria

Criteria #	Criteria Description
1	Deliver ephemerides for each ESMO mission to the CARA OSAs
2	Receive and process all CDMs for each nominal screening (3 times per day) for all missions
3	Deliver significant conjunction event report
4	Deliver RMM ephemerides for special screening by the CARA OSAs
5	Receive and process all CDMs from a special screening
6	Exercise HIE alert process/headcount request
7	Exercise the NASA HQ notification process
8	Exercise the Classified information communication process (not a classified event)
9	Generate and report metrics for CARA
10	Request and receive updated tasking for a secondary object
11	Execute an OD quality assessment with the CARA OSAs for a poorly tracked object, including requesting and receiving a 1v1
12	Exercise special screening during off hours
13	Complete the tool certification process for all required tool functions as stated in the Tools Certification Document ▪ Can take place prior to parallel operations start; at least two weeks of parallel operations must take place following the certification of all tools

Parallel Operations Success Criteria (cont'd)

Criteria #	Criteria Description
14	**Process the following types of events:** ▪ Process a routine "red" event (by CARA threshold), including tasking level increase requests, manual requests for updates, maneuver planning, maneuver screening and selection, and HQ notification/reporting ▪ Process a routine "yellow" event (by CARA threshold), including manual OD updates and tasking increase requests ▪ Process a routine "green" event (by CARA threshold) ▪ Exercise contact procedure for a potentially active secondary ▪ Process a red or yellow event with active secondary ▪ Process a red or yellow event with active secondary belonging to restricted country
15	**Process a red or yellow event with classified secondary** ▪ Process a late-notice red event (<12 hrs to TCA) ▪ Process a red or yellow event with active space weather event ▪ Exercise contacting the OSAs to get more information regarding space weather coefficients, and requesting more frequent tracking updates ▪ Process a red or yellow event with no Pc due to no O/O or secondary covariance (i.e. only one covariance so unable to generate combined covariance) ▪ Process a red or yellow event with inadequate 2-D Pc requiring Monte Carlo runs ▪ CARA will pick a case for this with low relative velocity and SpaceNav will be contacted for running the Monte Carlo simulation
16	**Exercise scenario where the CDM contains a non-positive-definite covariance in the last update prior to TCA**
17	**Exercise backup plan and contingencies outlined in the ESMO OPS CON**
18	**Exercise Breakup indications scenario** ▪ ESMO Mission or other break-up in close proximity
19	**Exercise forwarding CA data to CARA** ▪ All DOD source CA data received by the missions ▪ All CA related headquarters reporting produced by the missions ▪ Information related to CA decision making

Conclusion/Summary

- Devolution Working Group laid out and completed all steps needed to begin parallel operations
- Parallel Ops for ESMO began on 11/26 (CARA in shadow mode only)
- Any lessons learned from parallel ops will be folded back into documents/templates
- Hope to achieve all success criteria < 6 months
- Decision for permanent devolution will be based on completion of parallel ops and other future documentation creation (CARA Standard and Handbook, etc) and reviews (ORR)

BACKUP SLIDES

EOS Risk Thresholds at Decision Point

	Pc Thresholds	Odds Range	Course of Action	Sample Scenarios
Green	**$<1.0e^{-5}$**	1:100,000 to 0	**No DAM**	
Yellow	**($1.0e^{-4}$-$1.0e^{-5}$)**	1:10,000 to 1:100,000	**Altered DMU/No DAM**	Replan Nominal DMU burn time or execute DMU early <u>if available</u> For well-tracked objects with small miss distances
Orange	**($1.0e^{-3}$-$1.0e^{-4}$)**	1:1,000 to 1:10,000	**DAM**	Solution <u>within</u> mission/science requirements and low uncertainties
Red	**($1.0e^{-2}$-$1.0e^{-3}$)**	1:100 to 1:1,000	**DAM**	Execute even if <u>outside</u> mission/science requirements
Black	**$\geq 1.0e^{-2}$**	1:1 to 1:100	**DAM**	**Maneuver at all costs** Even if Ongoing Anomaly (Non-Maneuver Component)

- All unacceptable risks are mitigated
- Additional risks are mitigated within mission/science constraints
- Confidence in OD solution/risk accuracy must be considered as well

Operational CA Requirements

Function	CARA/OSA	CRMS/SpaceNav
Gather CDM/VCM data from JSpOC	✓	✓
Compute Probability of Collision	✓	✓
Process O/O information (mission ephem)	✓	✓
Generate Maneuver Trade Space Plot	✓	✓
Provide Summary Reports after each JSpOC screening update	✓	✓
Provide Full Secondary Information for High Risk Conjunctions	✓	✓
Provide Future Sensor Tracking Opportunities	✓	✓
Assess OD quality for each secondary and refine if needed	✓	✓ Capability exists
Update tasking for objects as required	✓	✓
Provide mitigation strategy for High Interest Events	✓	✓
Deliver Ephems to JSpOC for screening	✓	✓ Capability exists
Process screening results	✓	✓

Capability already exists on CRMS just not currently utilized for ESMO

Changes Needed for ESMO

Devolution Working Group created to address updates needed:

1. **Develop direct communication path to JSpOC/OSAs**
   - Communication path from O/O to O/O
   - Communication path for classified secondary
2. **Finalize direct ephem delivery path through Space-Track**
   - Successfully performed test in December with JSpOC crew (1 week)
   - Successfully performed second test (4/30 – 5/11) with Goddard OSAs (2 weeks)
   - **NOTE** - Deliver of ephems through SpaceTrack preserves ephemeris name
3. **Update ephem filenaming to JSpOC convention (FDS & CRMS)**
4. **Update documentation to reflect change**
   - Test Plan for No CARA Ops
   - Ops Concept Document (No CARA)
5. **Setup reporting paths and templates**